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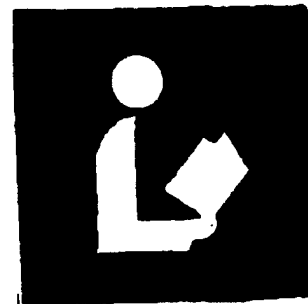
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Eval. of Dry Air Dehumidification

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10/7/88
Mr. Combs/SSC
Report No. SY50-88-044

Date: 21 September 1988

SUPPORT SYSTEMS DEPARTMENT TECHNICAL REPORT

Support Systems Department (SY50)
Systems Engineering Test Directorate
Naval Air Test Center
Patuxent River, Maryland 20670-5304

Title: Developmental Assist Program for the Evaluation of Dry Air Dehumidification

AIRTASK No.: A5525523/0523/8PP0232002

Work Unit No.: A55232-020J

Report Sequence Under Work Unit: First Report (Final)

Dates of Tests: 11 March - 29 August 1988

Location of Tests: NAVAIRTESTCEN; NAS, Cecil Field, FL; NAS, Jacksonville, FL; and
NAF, Mayport, FL

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Enclosures:

- (1) Specifics of Dehumidifier Hookups to Aircraft Tested
- (2) Test Data

INTRODUCTION

BACKGROUND

1. Dry Air Dehumidification is presently being used by European North Atlantic Treaty Organization military forces on operational aircraft to reduce the relative humidity (RH) within the aircraft. The claimed result is the elimination of corrosion of airframes, avionics systems, and propulsion systems with accompanying improvements in systems reliability and availability, as well as lowered support costs. In an effort to improve readiness and reduce maintenance costs, NAVAIRSYSCOM has instituted a two phased program to evaluate this technology for use on operational Navy aircraft. Phase I consisted of identifying flow rates of dry air required to reach a stable RH.

PURPOSE

2. NAVAIRSYSCOM requested that NAVAIRTESTCEN perform a developmental assist program to determine which of three flow rates (70, 150, or 300 standard cubic feet per minute (scfm)) of dry air is required to reduce and maintain the RH inside operational Naval aircraft to a level at which corrosion will be inhibited ($RH = 45\% \pm 5\%$) and to determine the time required.

DESCRIPTION OF EQUIPMENT

3. The desiccant wheel dehumidifier works on the absorption principal whereby a honeycomb wheel, which has been treated with a lithium chloride solution, absorbs moisture from air passing through it. The wheel is mounted inside the unit and is rotated at 8 revolutions per hour through two chambers: the dehumidifying chamber and the regeneration chamber. Ambient air is filtered and blown by a fan through the portion of the wheel in the dehumidifying chamber and is ducted into the aircraft as processed dry air. The moisture absorbed is removed from the wheel by ambient air which is filtered, heated, and blown by a second fan through the portion of the wheel in the regeneration chamber. The unit can run continuously and requires no cycle time to dry out the desiccant wheel because it is continuously regenerating itself. The unit that was supplied for testing is capable of supplying a variable flow rate of processed dry air from 0 to 600 scfm at 0.1 to 0.5 in. of water gauge (WG) pressure. It is powered by 440 VAC, 3 Phase, 60 Hz, electrical power which was provided by the utility power in the aircraft hangars.

SCOPE OF TESTS

4. Tests were conducted on operational P-3, F/A-18, and SH-60 aircraft. The scope of tests was limited to determining the following:
- Identify the flow rate of dry air that is required to dehumidify the test aircraft to an RH level of 45%.
 - Determine the time required to reach a 45% RH level with those flow rates of dry air.
 - Determine if an increase in flow rates will reduce the time required to dehumidify the test aircraft to an RH level of 45%.

DIST A

METHOD OF TESTS

5. The tests were conducted at NAVAIRTESTCEN; Naval Air Station, Cecil Field, Florida; Naval Air Station, Jacksonville, Florida; and Naval Air Facility, Mayport, Florida, as follows:

- a. The dehumidifier was used on test aircraft located inside hangars.
- b. Dry air was distributed throughout the aircraft by connecting the dehumidifier via flexible ducts to the test aircraft's ground cooling port and modified engine inlet covers (F/A-18 aircraft only). Enclosure (1) describes specifics of the hookups to each individual aircraft.
- c. Hygrothermographs were used to monitor and record ambient conditions inside the aircraft and were placed at critical areas of investigation. A handheld digital hygrothermometer was used to calibrate the hygrothermographs prior to each test.
- d. Airflow rates of dry air delivered to the test aircraft were established by using a hot wire anemometer inserted directly into the flexible duct. Numerous readings were taken at different locations across the cross sectional area of the duct to determine an average air velocity. The average velocity was then multiplied by the cross sectional area of the duct to determine flow rates. Airflow adjustments were made by means of a gate valve located on the dehumidifier discharge port.
- e. After establishing a baseline RH level in the critical areas prior to dehumidification, the dehumidifier was activated and allowed to run with the aircraft left undisturbed with cabin doors, canopies, and avionics panels secured.
- f. Tests were repeated on the test aircraft at flow rates of 70, 150, and 300 scfm as required.

RESULTS AND DISCUSSION

GENERAL

6. In all tests, a reduction in RH levels was observed. Not all areas surveyed inside the aircraft responded to dehumidification simultaneously. A number of dynamic factors, such as ambient RH fluctuations, gusting winds, changes in weather patterns, temperature changes, solar radiation, etc., was responsible for some inconsistent readings. These changes in test site environmental conditions made each test unique and made repeatability difficult within the scope of these tests.

7. In general, increasing the flow rates of dry air above those required to dehumidify the aircraft had three effects: a decrease in the time required for the monitored areas to achieve 45% RH, a decrease in the differences in time between the monitored areas to achieve 45% RH, and a decrease in the lowest stabilized RH level achieved.

SPECIFIC

8. A total of five tests was conducted on P-3 aircraft: two utilizing a flow rate of 150 scfm and three utilizing a flow rate of 300 scfm. No tests were conducted utilizing 70 scfm due to the time required to dehumidify this size of aircraft. The data from those tests were compiled and are presented in graphical form in enclosure (2). Results of those tests are as follows:

- a. A flow rate of 150 scfm of dry air dehumidified the P-3 aircraft to an RH level of 45%.
- b. The time required to reach a 45% RH level at 150 scfm ranged from 1.5 to 6 hr. The RH continued to fall to a stabilized level of 40%.
- c. Increasing the flow rate of dry air to 300 scfm reduced the time required to achieve 45% RH level inside the test aircraft by as much as 4 hr when ambient RH was in the 70 to 90% range. When the ambient RH was in the 40 to 60% range, the higher flow rate had minimal impact on the time required to reach 45% RH level. The use of a higher flow rate also resulted in a lower stabilized RH level of 15 to 20% being achieved during all ambient weather conditions tested.

9. A total of five tests was conducted on the F/A-18 aircraft: three utilizing a flow rate of 70 scfm and two utilizing a flow rate of 150 scfm. During one test, a hygrothermograph was placed inside the starboard engine nacelle (outside of the gas path) with no change in RH noted. The data from those tests were compiled and are presented in graphical form in enclosure (2). Results of those tests are as follows:

- a. A flow rate of 70 scfm adequately dehumidified the F/A-18 aircraft except for the cockpit area. RH levels in the fuselage avionics bays, the radar equipment bay, and both engines dropped to 45%, but RH levels inside the cockpit area would not reduce to that level during the entire test periods. Increasing the flow rate to 150 scfm caused the RH levels inside the cockpit to drop to the 45% RH level.
- b. At a 70 scfm flow rate, the time required for the avionics and radar equipment bays to reach a 45% RH level was less than 1 hr. The engines required 2 hr for the RH to reach the 45% level. Cockpit readings never dropped below 50% during any of the tests at 70 scfm. At a 150 scfm flow rate, a reduction in the time required for the avionics bays, radar equipment bay, and engines was negligible, but the cockpit RH levels dropped to 45% in 1.5 to 2 hr.
- c. A flow rate of 300 scfm could not be attained due to the low pressure provided by the dehumidifier (0.1 to 0.5 in. of WG) coupled with the inherent airflow restrictions of the 4 in. duct and the plumbing of the aircraft environmental control system (ECS). The maximum airflow achievable was limited to 172 scfm.

10. A total of five tests was conducted on the SH-60 aircraft: three utilizing a flow rate of 70 scfm and two utilizing a flow rate of 150 scfm. The data from those tests were compiled and are presented in graphical form in enclosure (2). Results of those tests are as follows:

- a. A flow rate of 70 scfm adequately dehumidified the SH-60 aircraft to an RH level of 45%.
- b. The time required to reach a 45% RH level at 70 scfm ranged from 0.5 to 1 hr. The RH continued to fall to a stabilized level of 15 to 20%.
- c. Increasing the flow rate of dry air to 150 scfm had minimal impact on the time required to reach a 45% RH level. The higher flow rate reduced the time required to reach the lowest stabilized RH level from approximately 8.5 hr to approximately 3.5 hr. A flow rate of 300 scfm was not attainable on the SH-60 due to the inherent airflow restriction of the 4 in. duct.

CONCLUSIONS

GENERAL

11. Within the scope of these tests, it is concluded that Dry Air Dehumidification can reduce and maintain RH levels inside the P-3, F/A-18, and SH-60 aircraft to 45% or less.

SPECIFIC

12. Conclusions of the tests conducted on the P-3 aircraft are as follows:

- a. A flow rate of 150 scfm of dry air dehumidified the P-3 aircraft to an RH level of 45% (paragraph 8.a).
- b. The time required to reach a 45% RH level at 150 scfm ranged from 1.5 to 6 hr (paragraph 8.b).
- c. Increasing the flow rate of dry air to 300 scfm reduced the time required to achieve 45% RH when ambient RH was in the 70 to 90% range. It also resulted in a lower stabilized RH level being achieved (paragraph 8.c).

13. Conclusions of the tests conducted on the F/A-18 aircraft are as follows:

- a. A flow rate of 70 scfm adequately dehumidified the F/A-18 aircraft except for the cockpit area. Increasing the flow rate to 150 scfm caused the RH levels inside the cockpit to drop to the 45% RH level (paragraph 9.a).
- b. At a 70 scfm flow rate, the time required for the avionics and radar equipment bays to reach a 45% RH level was less than 1 hr. The engines required 2 hr for the RH to reach the 45% level. At a 150 scfm flow rate, a reduction in the time required for the avionics bays, radar equipment bay, and engines was negligible, but the cockpit RH levels dropped to 45% in 1.5 to 2 hr (paragraph 9.b).
- c. A flow rate of 300 scfm could not be attained due to the inherent airflow restrictions of the dehumidifier duct and the aircraft ECS plumbing (paragraph 9.c).

14. Conclusions of the tests conducted on the SH-60 aircraft are as follows:

- a. A flow rate of 70 scfm adequately dehumidified the SH-60 aircraft to an RH level of 45% (paragraph 10.a).
- b. The time required to reach a 45% RH level at 70 scfm ranged from 0.5 to 1 hr (paragraph 10.b).
- c. Increasing the flow rate of dry air to 150 scfm had minimal impact on the time required to reach a 45% RH level. The higher flow rate reduced the time required to reach the lowest stabilized RH level from approximately 8.5 hr to approximately 3.5 hr (paragraph 10.c).

RECOMMENDATIONS

GENERAL

15. It is recommended that the higher flow rates be used for Phase II testing to reduce the amount of time required to dehumidify the aircraft and create a more uniform environment inside the aircraft.

SPECIFIC

- 16. Use a flow rate of 300 scfm to dehumidify the P-3 aircraft.
- 17. Use a flow rate of 150 scfm to dehumidify the F/A-18 aircraft.
- 18. Use a flow rate of 150 scfm to dehumidify the SH-60 aircraft.

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SPECIFICS OF DEHUMIDIFIER HOOKUPS TO AIRCRAFT TESTED

1. In all tests conducted on the P-3 aircraft, the dehumidifier was attached to the aircraft utilizing the 8 in. duct and coupling assembly commonly used with the A/M32C-17 Mobile Air Conditioning Unit. The dry air was distributed throughout the aircraft by attaching the coupling to the aircraft ECS ground cooling port located just aft of the nose gear doors. The ECS basically dumps conditioned air into the cabin spaces and makes its way to the cabin outflow valve through the avionics cabinets. Hygrothermographs were positioned in nine locations inside the aircraft to monitor differences in RH levels that might occur due to the size of the aircraft and the relatively low airflows used.
2. The dehumidifier was attached to the F/A-18 aircraft utilizing a 4 in. duct equipped with an MS 16051-1 coupling commonly used with the NR-5C Mobile Air Conditioning Unit. Dry air was distributed throughout the aircraft by attaching the coupling to the aircraft ECS ground cooling port located on the bottom of the left engine nacelle just aft of the intake. The F/A-18 ECS directs conditioned air into all avionics bays and the cockpit. Dry air was also used to dehumidify the engines. An airflow distribution manifold was fabricated to facilitate 2 in. hoses for engine dehumidification and installed in series with the 4 in. flexible duct. To control the amount of dry airflow to the engine's 3/8 in. orifice, plates were installed into the distribution manifold. Hygrothermographs were positioned in fuselage avionics bays 13R, 14R, 13L, 14L, the radar equipment bay, inside the cockpit on the pilot's seat and in the equipment bay aft of the pilot's seat, and inside both engine tailpipes.
3. Although the SH-60 aircraft is equipped with an ECS, there are no provisions for ground cooling. Connecting the dehumidifier to the aircraft required that NAVAIRTESTCEN fabricate a fixture which installed on the small sliding panel on the cabin door. Dry air was blown into the cabin and distributed randomly throughout the aircraft. Hygrothermographs were positioned at the pilot's control pedals, the sensor console operator station, on avionics racks inside the cabin, inside the nose avionics bay, on the cabin floor just aft of the pilot's center console, and inside the transition area aft of the fuel cell.

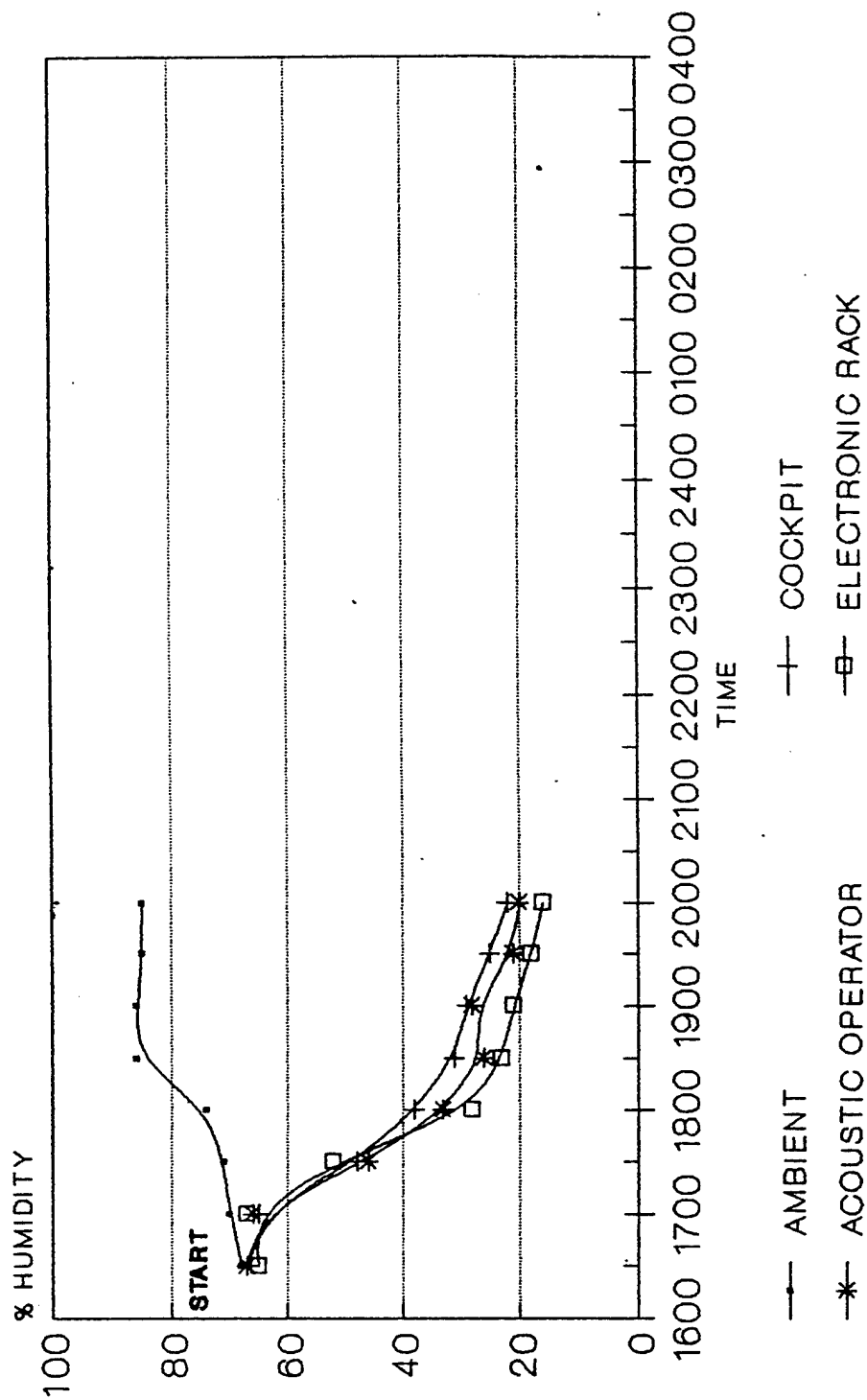
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TEST DATA

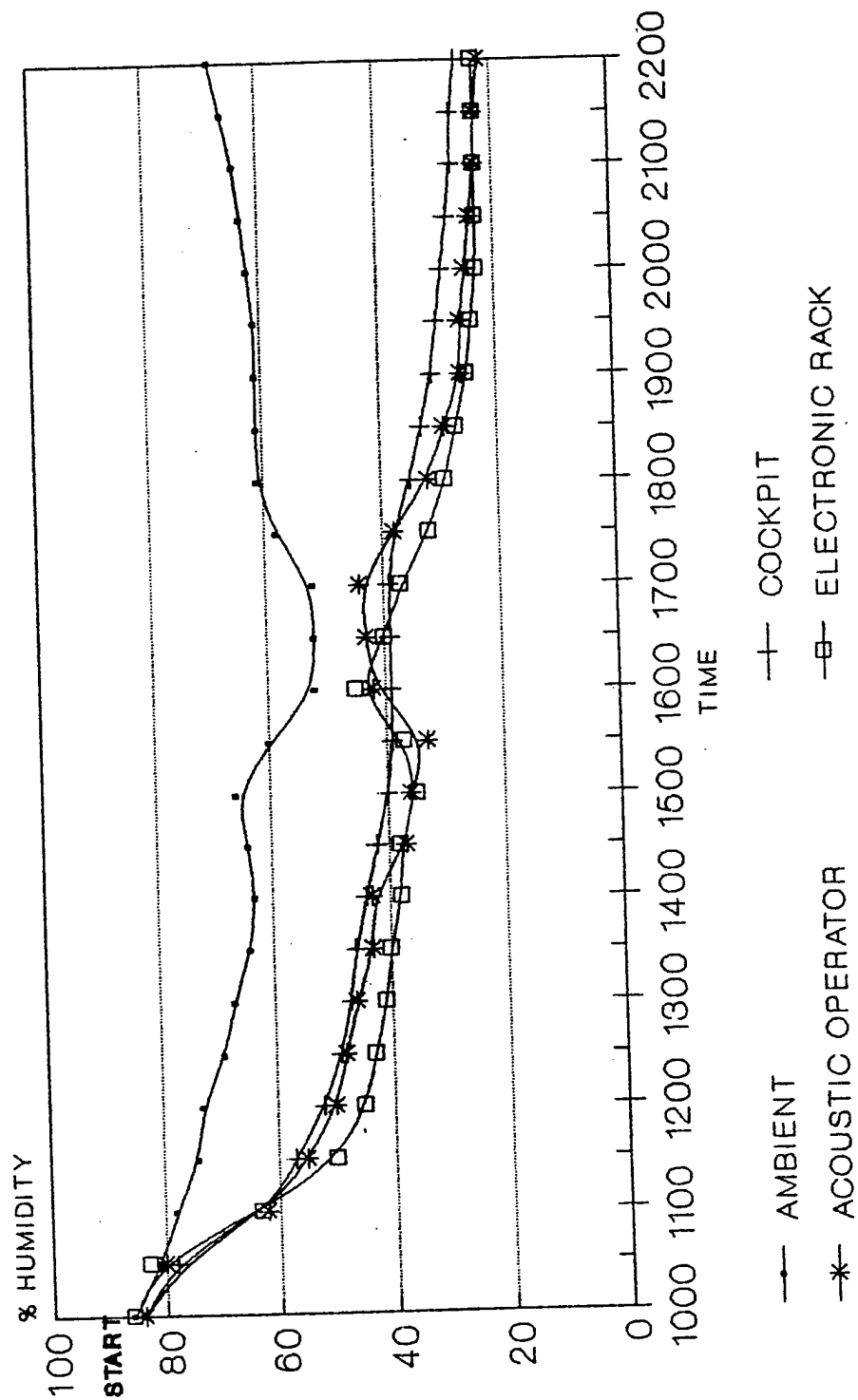
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HUMIDITY READINGS P-3 ORION

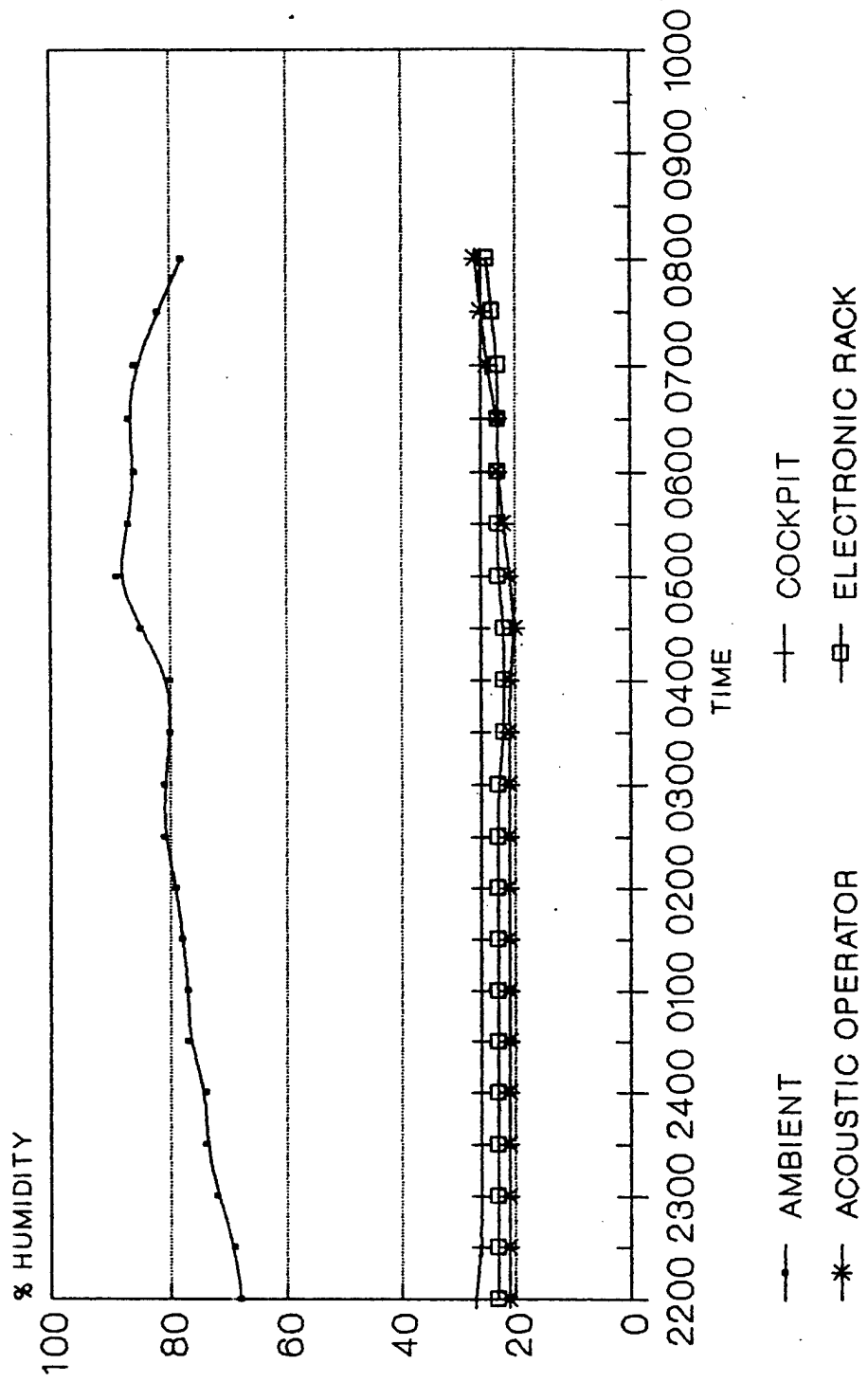
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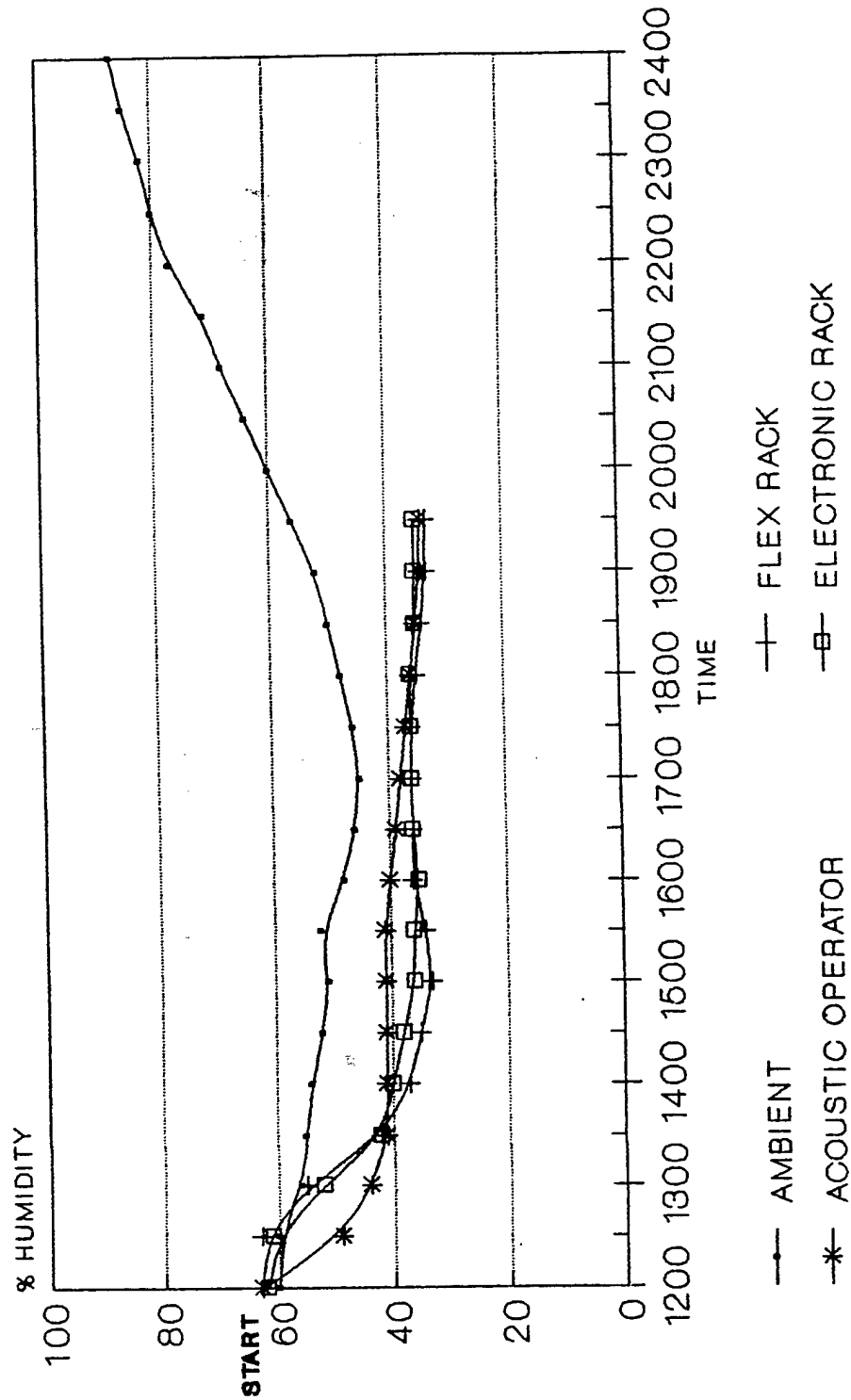
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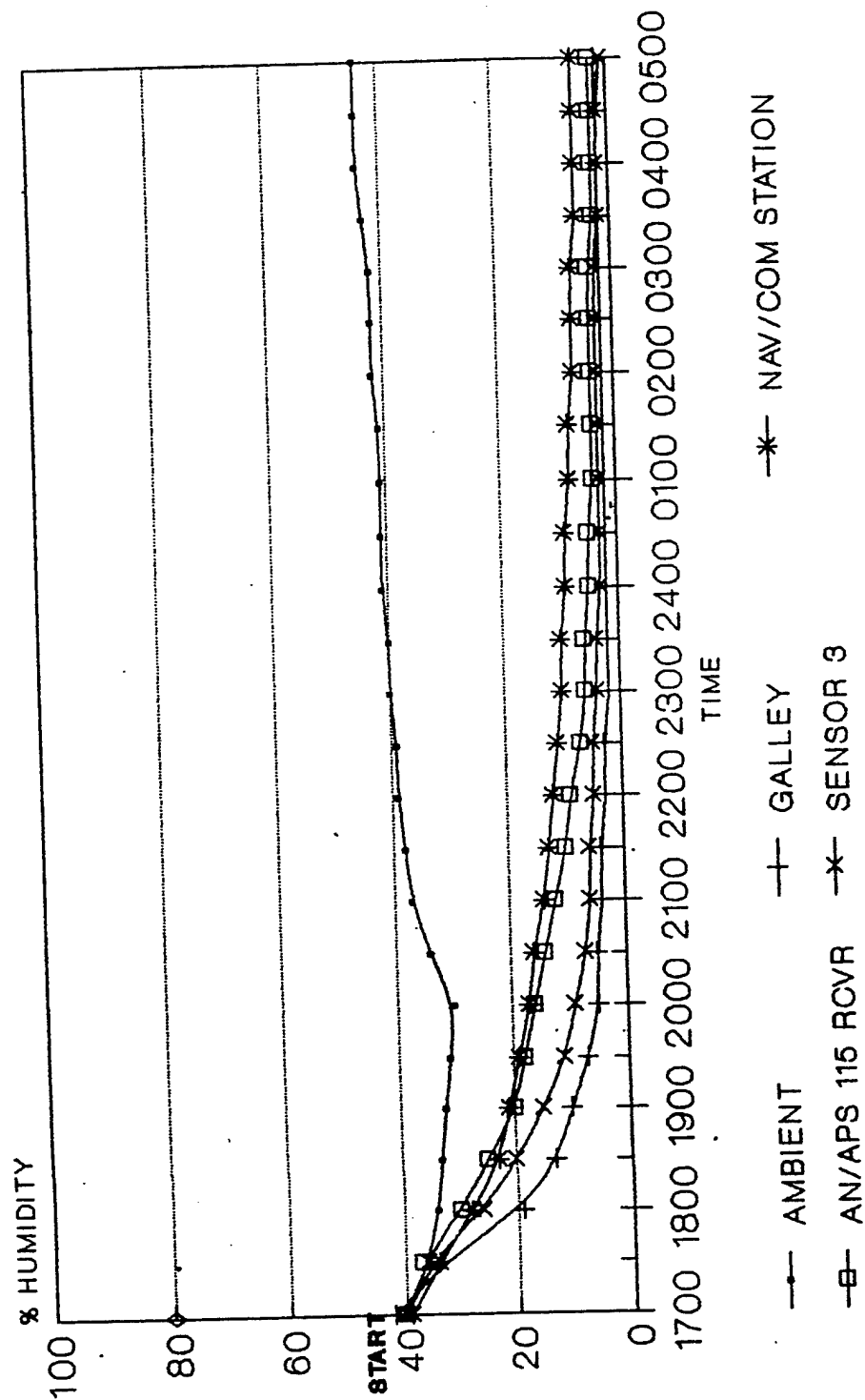
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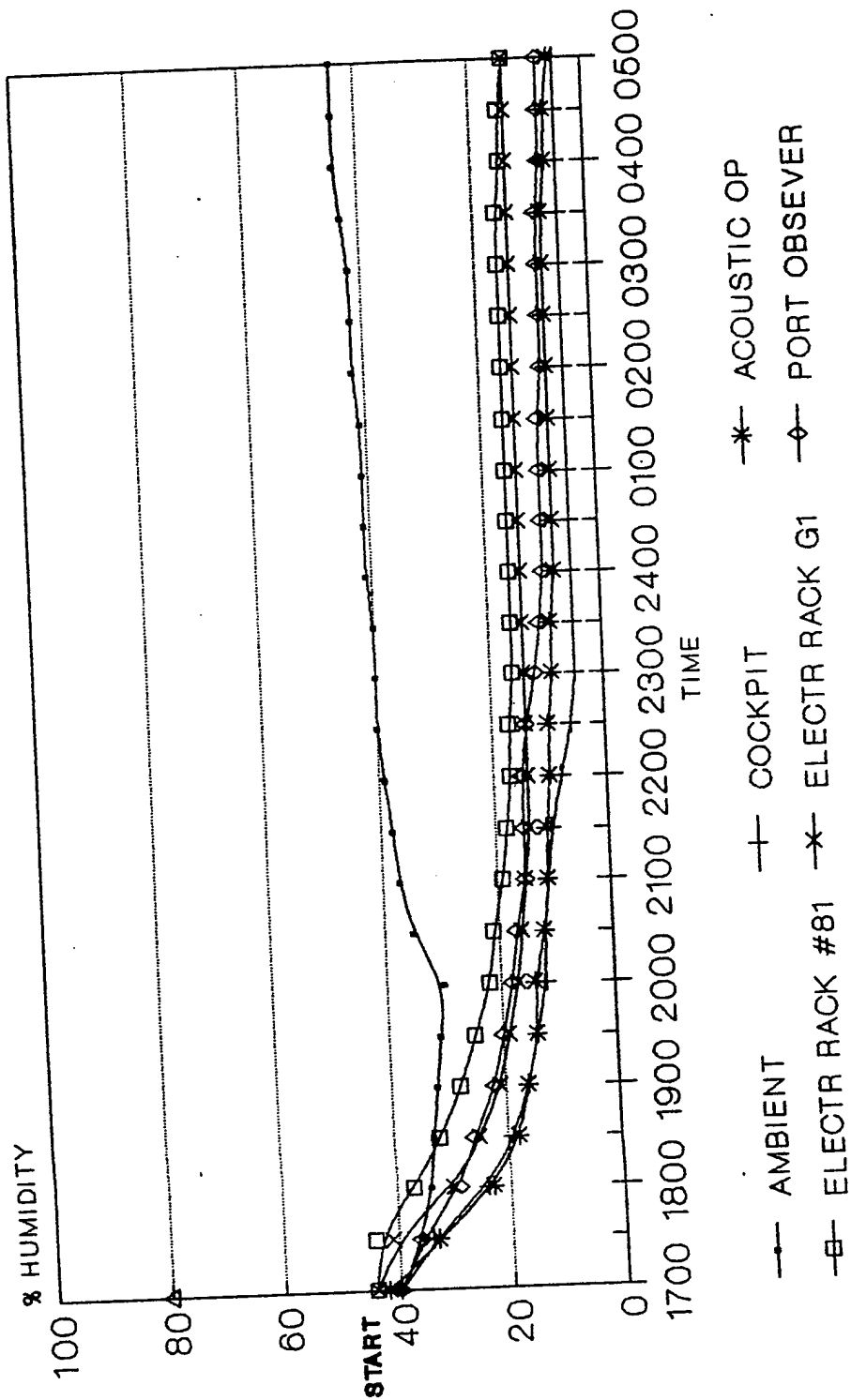
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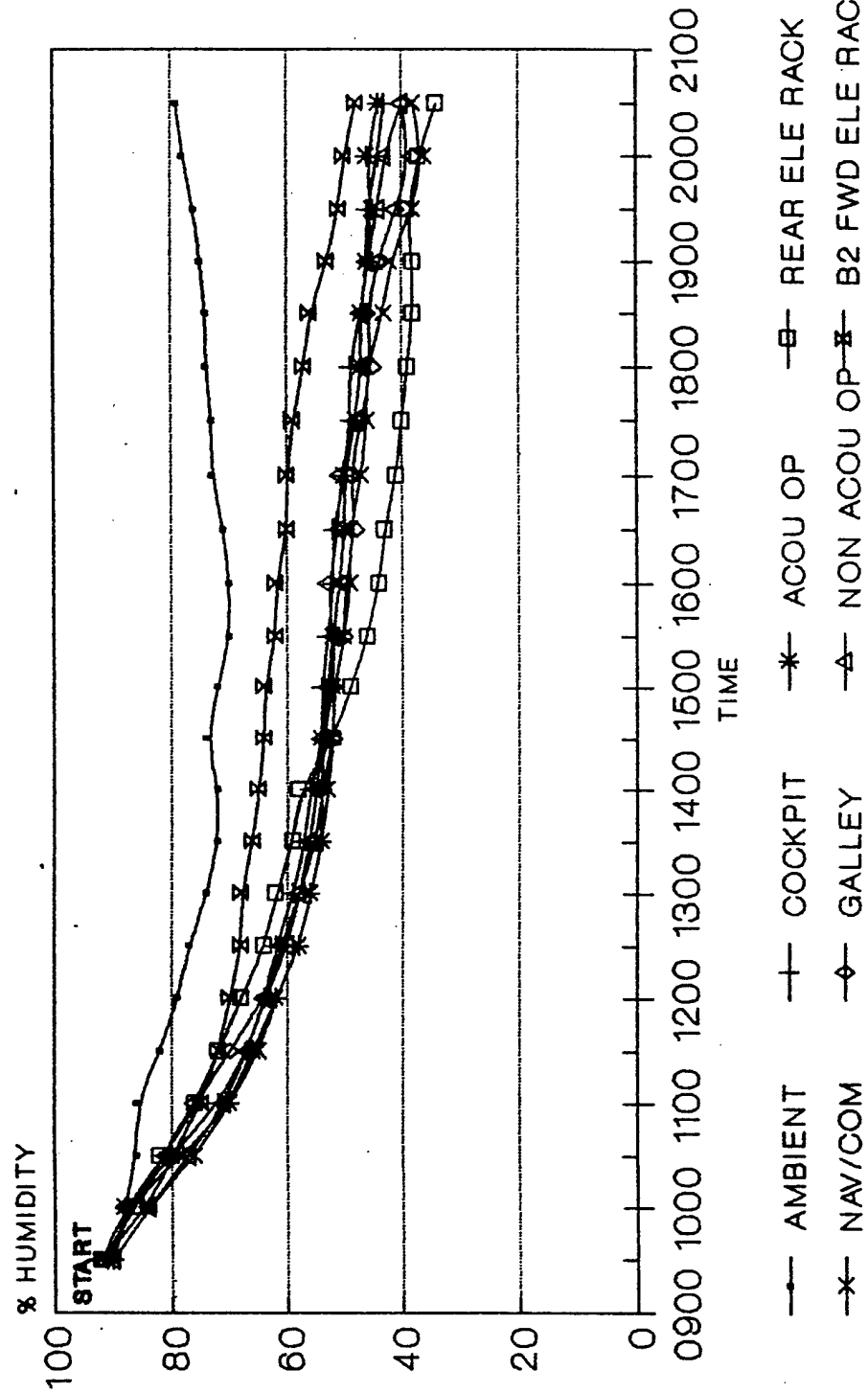
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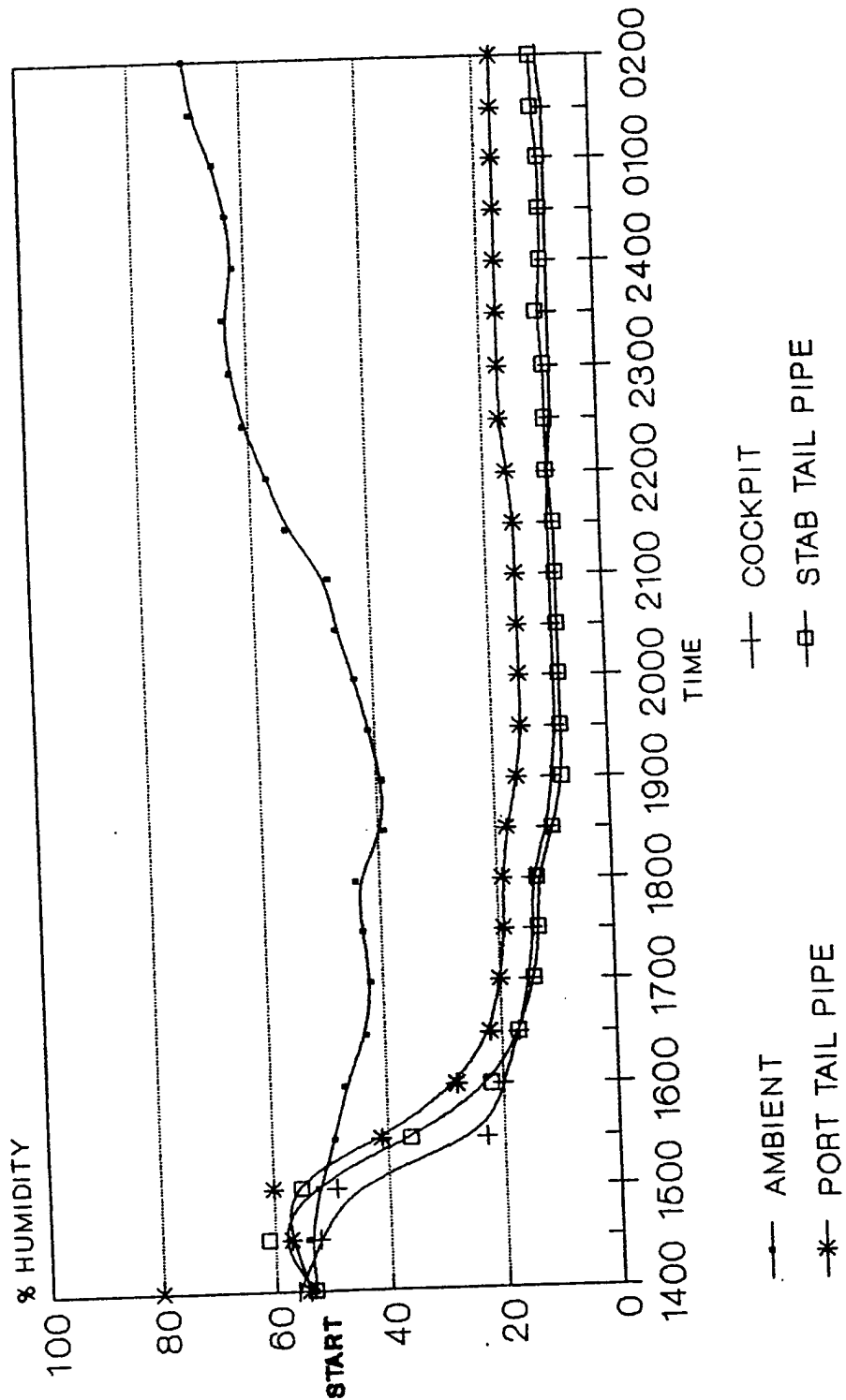


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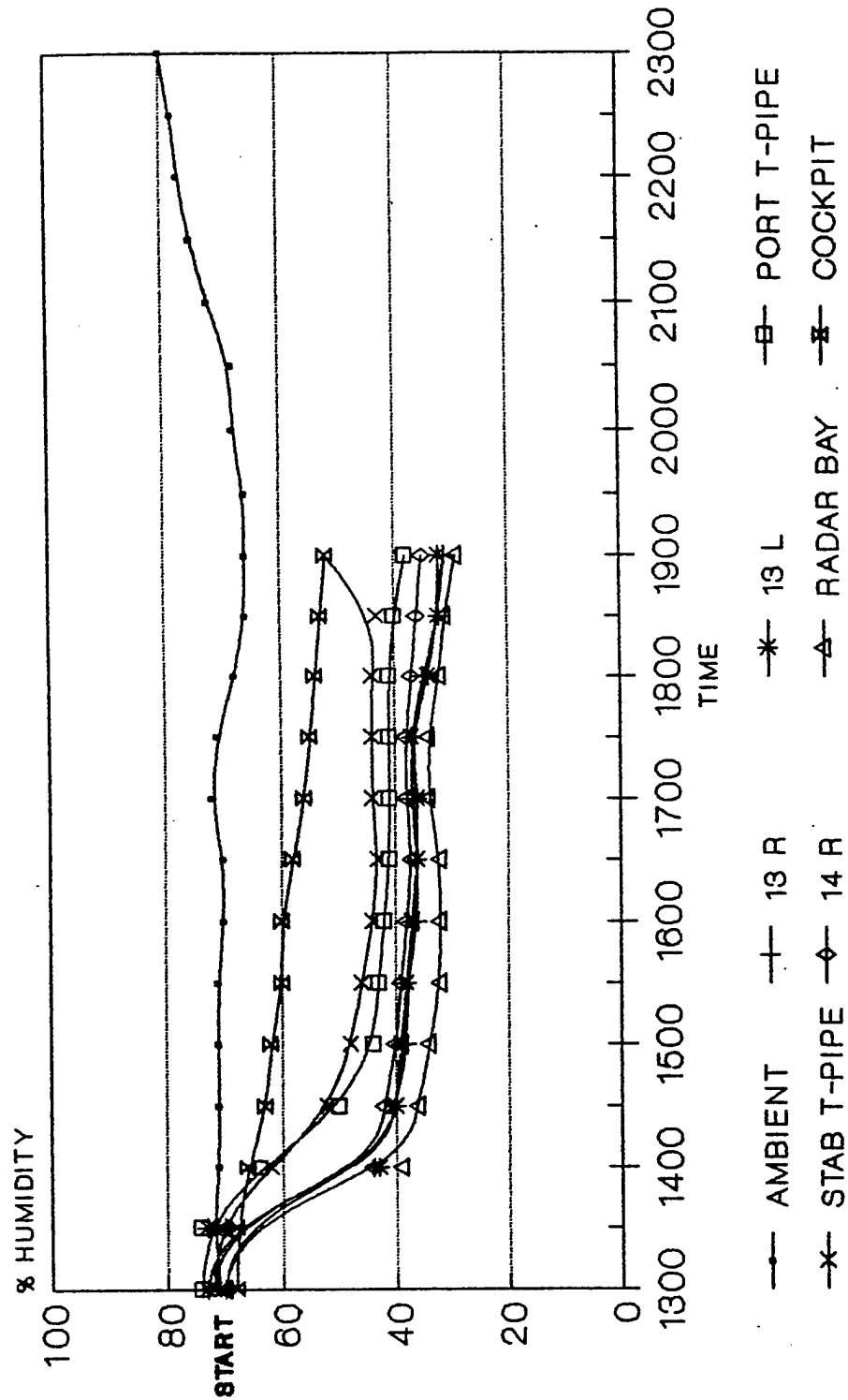


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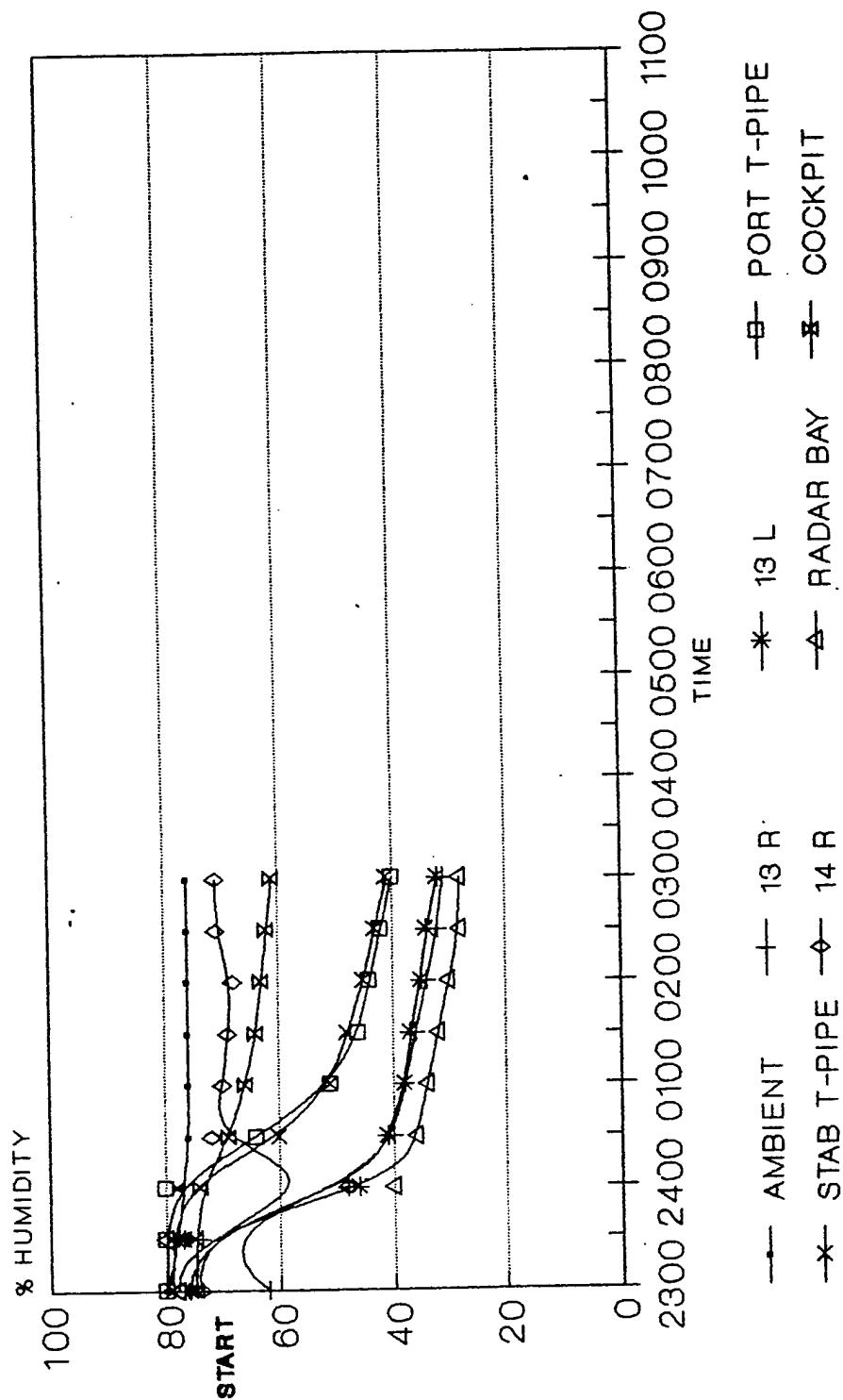


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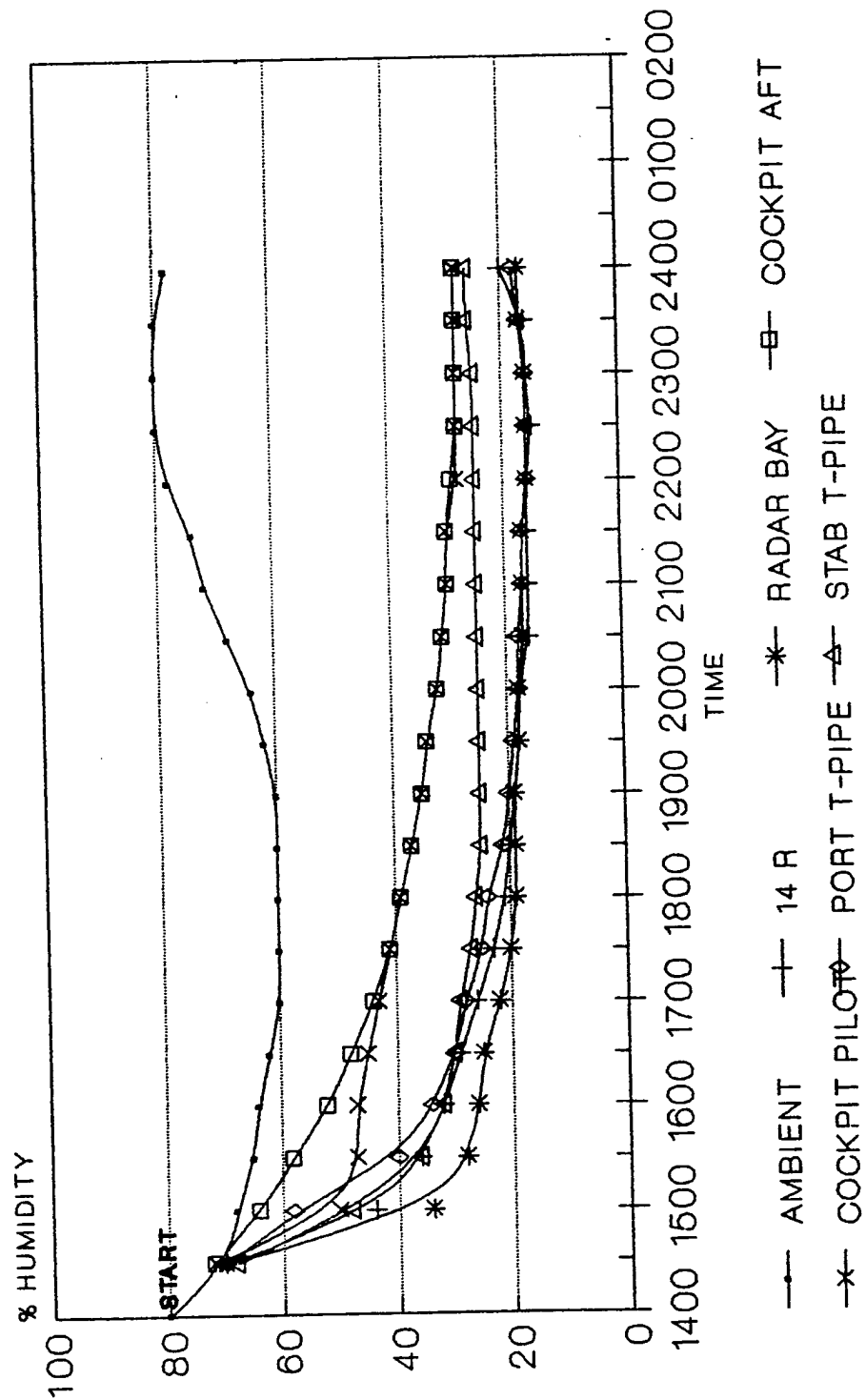


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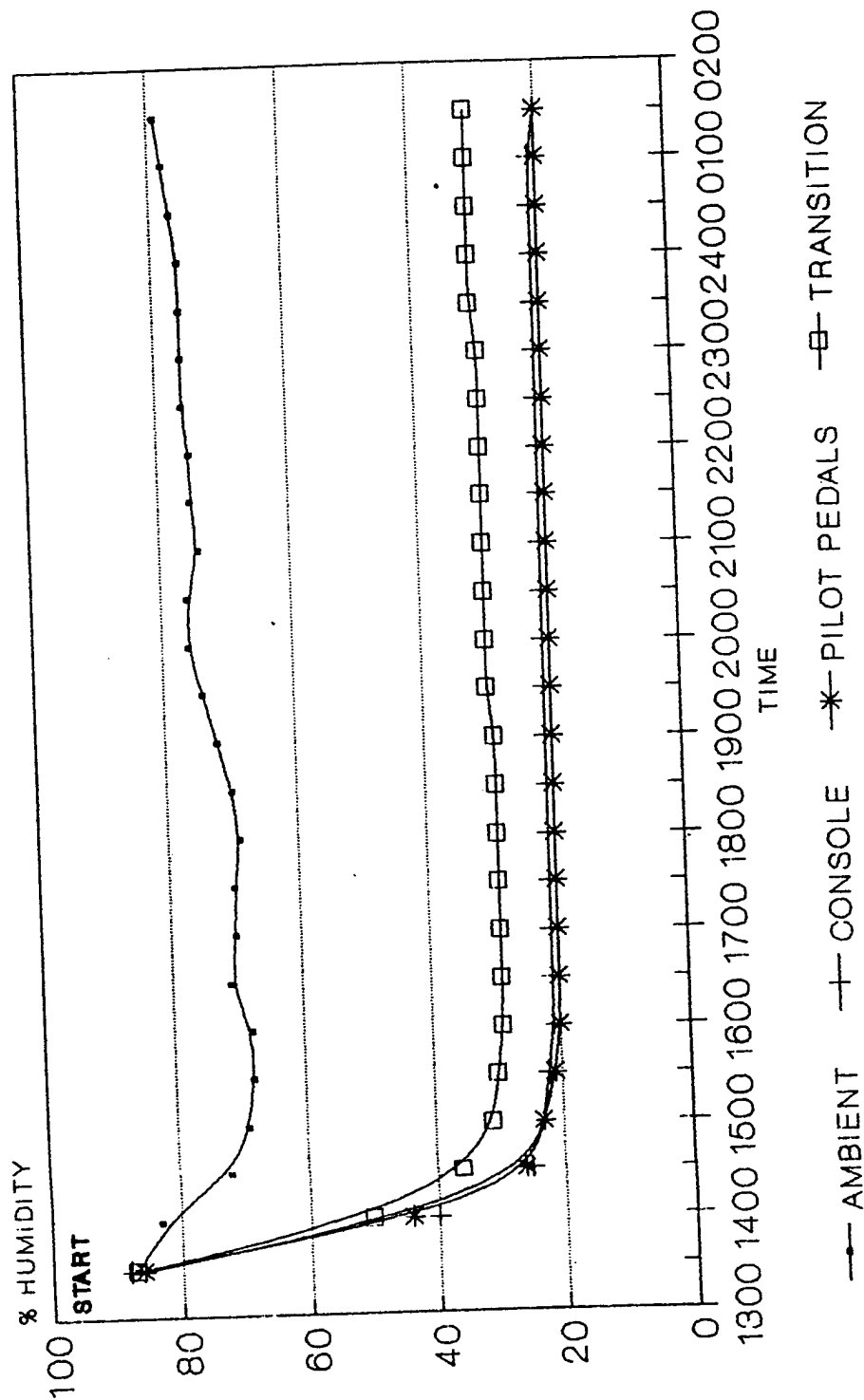
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NAVAIRTESTCEN 7-28-88 150 CFM



HUMIDITY READINGS SH-60 SEAHAWK

MAYPORT, FL 4-25-88 150 CFM



HUMIDITY READINGS SH-60 SEAHAWK

NAVAIRTESTCEN 6-15-88 70 CFM

